Original design & manufacturing of a New Upstream Rotating Measurement System for gas turbine exhaust gases studies

- Development of an advanced system for pollutant measurement -

Acronym: *NURMSys*
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Final report

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TURBOMECA
Avenue Joseph Szydlodski
BP 11, F.64511 Bordes

List of participants:

NOTELET Guillaume g.notelet@akira-technologies.fr	Akira Technologies
ESQUERRE Stéphane stephane.esquerre@turbomeca.fr	Turbomeca, DIR/MAV/EC
TASTET Benjamin benjamin.tastet@turbomeca.fr	Turbomeca, DIR/MAV/EC
CABRINI Jérôme jerome.cabrini@turbomeca.fr	Turbomeca, DIR/MAV/EC
CHAMPION-RÉAUD Jean-Louis jean-louis.champion@turbomeca.fr	Turbomeca, DIR/MAV/EC
VISENTINI Roberta roberta.visentini@turbomeca.fr	Turbomeca, DIR/MAV/EC

Diffusion list:

LOUMÉ Sylvain s.loume@akira-technologies.fr	Akira technologies (*)
NOTELET Guillaume	Akira Technologies (*)
AGUERRE Franck franck.aguerre@turbomeca.fr	Turbomeca, DIR/MAV/EC (+)
ESQUERRE Stéphane	Turbomeca, DIR/MAV/EC (+)
TASTET Benjamin	Turbomeca, DIR/MAV/EC (+)
CABRINI Jérôme	Turbomeca, DIR/MAV/EC (+)
CHAMPION-RÉAUD Jean-Louis	Turbomeca, DIR/MAV/EC (+)
VISENTINI Roberta	Turbomeca, DIR/MAV/EC (+)
LEBELLE Alexandre alexandre.lebelle@turbomeca.fr	Turbomeca, DVH/CG (+)
ESCOURROU Pierre pierre.escourrou@turbomeca.fr	Turbomeca, DT/ PMR (+)
SEINTURIER Éric eric.seinturier@turbomeca.fr	Turbomeca, DT/ PMR (+)
	Clean Sky J.U.(°)

(*)AKIRA Technologies	*(+) Turboméca*	*(°)Clean Sky JU*
ZA St Frédéric *Rue de la Galupe* *F.64100 Bayonne, France*	*Avenue Szydlowski* *BP 11* *F.64511 Bordes, France*	*TO56, 4th floor,* *office 10* *B - 1049 Brussels, Belgium*
Phone: +33.5.59.50.11.39 *Fax: +33.5.59.55.58.18*	*Phone: +33.5.59.12.50.00* *Fax : +33.5.59.53.15.12*	*Phone: +32-22.21.81.68*

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1 FINAL MEETING:

The final meeting of the NURMSys program has been held at Turbomeca the 18th of October. The present document summarises the different points developed during this meeting.

2 REMIND OF OBJECTIVES :

The objectives of the NURMSys program consists on the design and manufacturing of a **N**ew **U**pstream **R**otating **M**easurement **Sys**tem for gas turbine exhaust gases analysis.

‘’**AKIRA technologies’’**, a company based in Bayonne (64), is identified as the unique partner.

3 TECHNICAL SPECIFICATIONS

We remind here the main technical specifications of the project.

The **N**ew **U**pstream **R**otating **M**easurement **Sys**tem, NURMSys (in French NATIA, for ‘’Nouvel Anneau Tournant Intégré Amont’’) will be based on 4 easily removable rakes (developed by Turbomeca) assembled on a rotating shaft placed inside the combustor module and driven by an electrical motor. Probe displacement and data acquisition (temperature, gas concentration from analysers, pressures…) will be computer controlled. Simultaneously, average values of experimental conditions will be collect by the computer and gathered to instantaneous measurements.

The project consists in the detailed study and the manufacturing of an embedded system which satisfies the following requirements:

- The rotating shaft is to be fitted with 4 measurement rakes, 2 for temperature measurements (typically 5 thermocouples each) and 2 for gas sampling, (one averaged and one at 5 discrete radii),
- The air inlet temperature is up to 450°C, and is therefore the highest value of temperature reached in the upstream part of the test module,
- Rakes must be easily removable,
- Minimum inner diameter of the combustor: 150 mm,
- Maximum shaft diameter: 60 mm,
- The analysis must be performed continuously (360° in 12 min) or step by step (angular resolution of 0.5 °). In this case, higher speed is allowed: typically 1 RPM,
- A solution with absolute positioning system is preferred,
- According to the delay in gas analysis, a sector of 370° should be investigated,
- As far as possible, the gas sample must be maintained at a constant temperature of 190° C to avoid mainly water and also Unburned Hydro Carbons (UHC) condensation within tubes,
- The rotating system geometry has to remain compatible with the actual module dimensions and interfaces (flanges),
- Input (air and water cooling, drive mechanism of the shaft) and output (thermocouples, gas sampling tubes) will be performed trough the upstream casing arms (up to five),
- Thermal exchange with the incoming air flow must be as low as possible in order to avoid thermal distortions in azimuth at the combustor entry,
- water cooling is required both for the rake integrity and for chemical quenching purposes at the level of the probing holes,
- Air passages are required for the cooling of downstream parts,

- As far as possible, data acquisition boards (PXI rake) should be provided by National Instrument and the soft developed under the Labview software,
- The soft will manage the shaft motion and the local data acquisition : gas analysis concentration and temperature measurements, as well as the angular shaft location and any measurements (mass or flow temperatures, pressures, ..) required for safety reasons,
- The software will also collect the mean flow characteristics (typically pressures, temperatures and flow rate of both inlet air and kerosene) from TURBOCAT (test rig IHM) by means of file transfer using an FTP link,
- The mean flow characteristics will be gathered to the instantaneous one by the software,
- Gas analysis concentration should be collected electrically (4-20 mA or 0-10 V standards) or by means of an ethernet link,
- Temperature measurements should be collected directly or after amplification (0-5V) with a maximum bandwidth of 10 kHz per channel (in case of the use of non sheathed thermocouples)
- Additional data (pressure, light intensity) should be collected with the same bandwidth of 10 kHz per channel,

Several technical specifications have been produced par TM:

- Mechanical specifications:
  - **cdc-méca-NURMSys-V1.doc** (16/02/2011)
- Electrical, electronic and software specifications:
  - **cdc-elec-NURMSys-V1.doc** (15/06/2011)

4 WORK DESCRIPTION

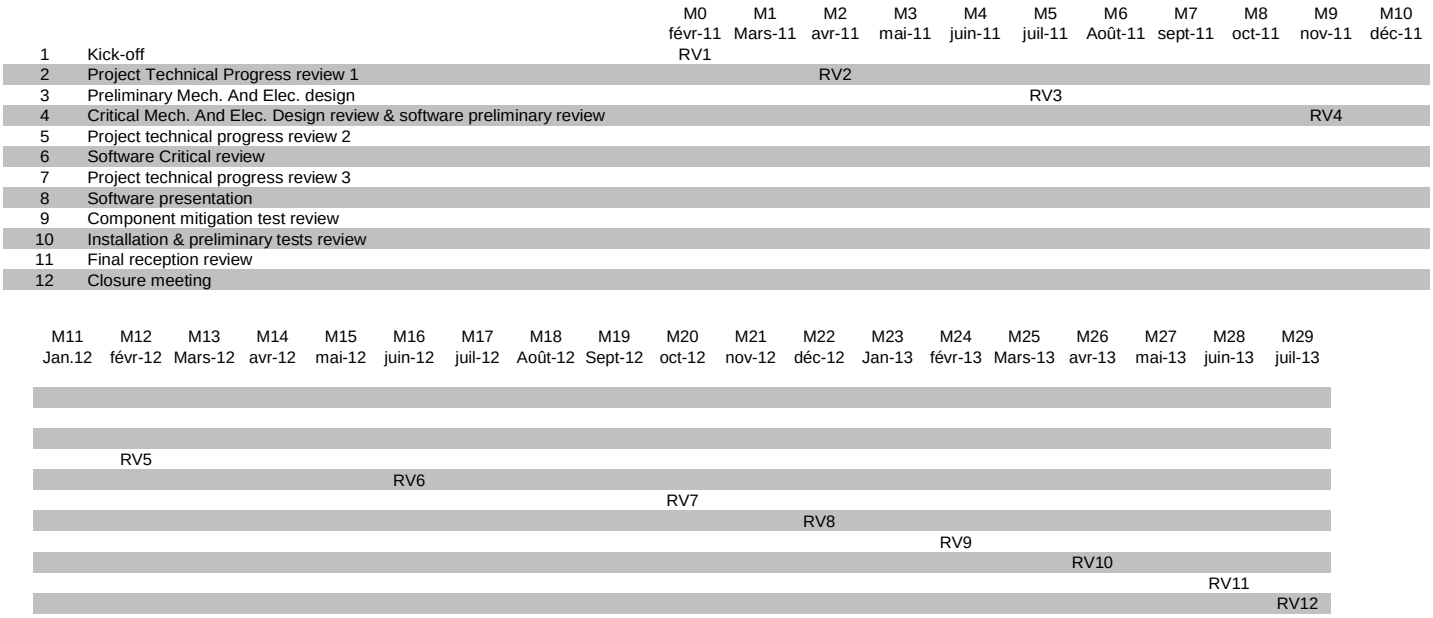
4.1 WORK PACKAGES

The activity is split in 6 work packages.

NURMSys
WP 1: Concept mechanical & compactness study, parts design & manufacturing engineering
WP 2: Displacement & Acquisition system study (Hardware and Software)
WP 3: Component test series for technological risk mitigation purpose
WP 4: Electrical & mechanical sub-system assembly, final mounting
WP 5: Installation at Topic Leader, Start up and preliminary tests
WP 6: Project Management & Topic Leader contact
Machined parts manufacturing delays

4.2 MILESTONES

The work started with the kick-off meeting (W06 of 2011). Originally planned over 12 months, the work achievement required **29 months**, mainly due to the complexity of the project. The realized schedule is given in the following table. It indicates also the milestones (detailed technical reviews) at the end of each corresponding task.



Originally, the number of milestones was limited to 4. According to the project complexity, the number was increased to 12 in order to ensure a better survey. A periodic reporting on a period of two weeks was organized to follow the project development.

4.3 LIST OF DELIVERABLES

Despite the delay, the list of deliverables did not change. Their contents, as wall as the actual date, are summarized in the following table.

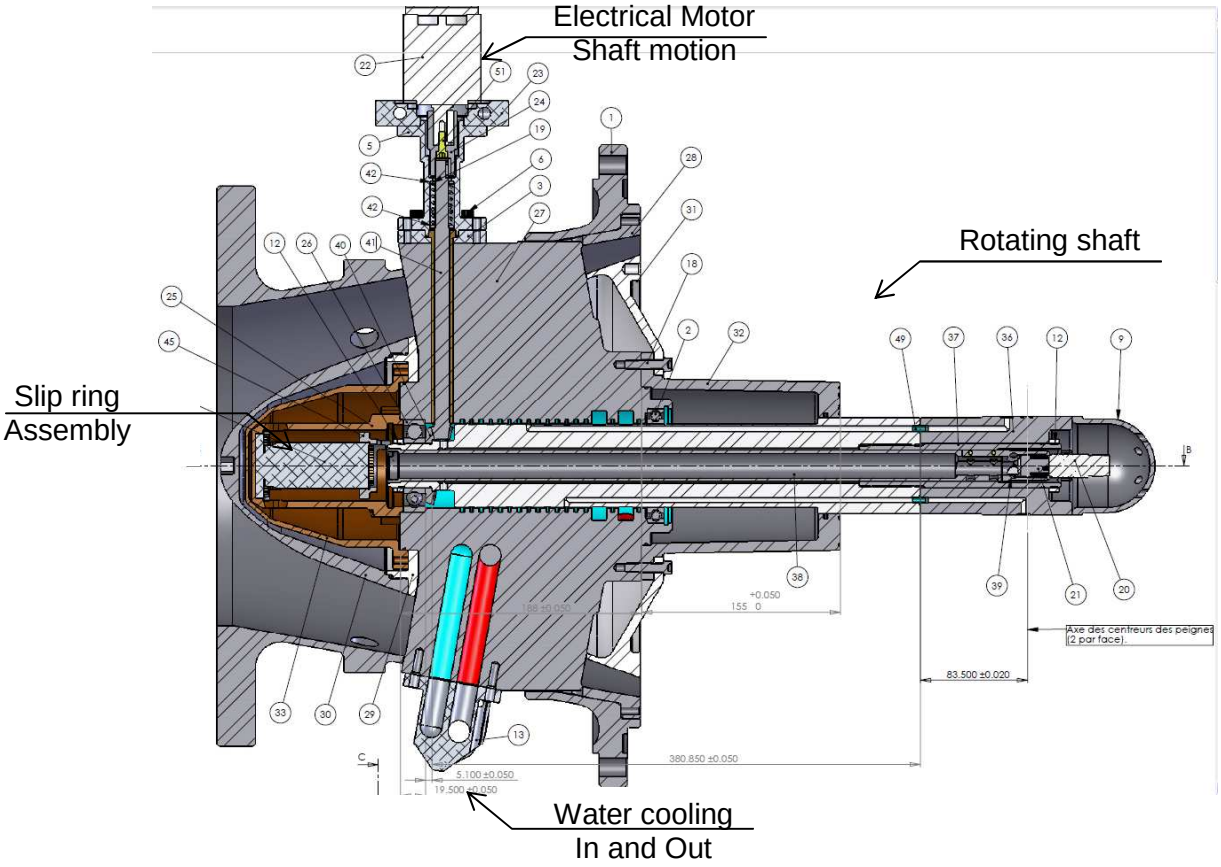
Number	Title	Status
1	Detailed design *NURMSys_Deliv1_DetailedDesign.pdf*	Down
2	Machined parts with final dimension *NURMSys_Deliv2_MachinedParts.pdf*	Down
3	Complete electrical & electronic design (plans & components) *NURMSys_Deliv3_Complete Electric&Electronic Design.pdf*	Down
4	Software complete version *NURMSys_Deliv4_Software Complete Version.pdf*	Down
5	Test report and final component choice *NURMSys_Deliv5_Test Report & Final Component choice.pdf*	Down
6	Preliminary reception *NURMSys_Deliv6_Preliminary Reception.pdf*	Down
7	Tests on Topic's leader Test bench *NURMSys_Deliv7_ ReceptionTest.pdf*	Down

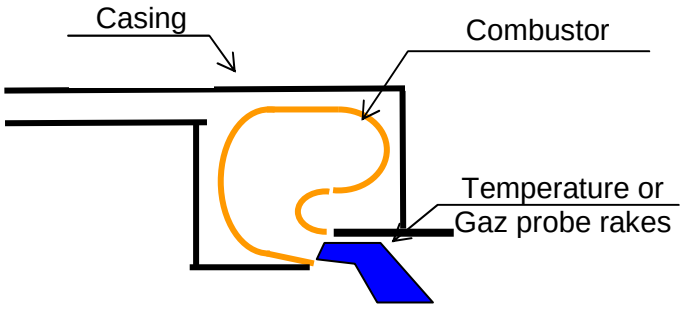
5 WORK COMPLETION

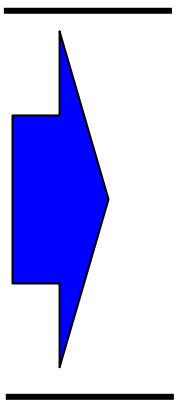
In the framework of this project, **AKIRA** performed the design and the manufacturing of the module called ''**NATIA**'' (for **N**ouvel **A**nneau **T**ournant **I**ntégré **A**mont). It consists on two main parts: the module itself and the acquisition rack. The acquisition and the rakes displacement is controlled via a Labview software also developed by **AKIRA** for this purpose.

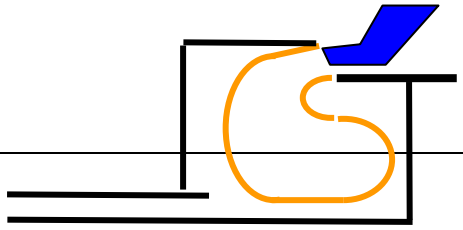
5.1 MODULE

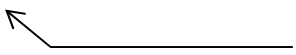
A drawing of the module is given in ***Figure 1***, while ***Figure 2*** provide two photos.











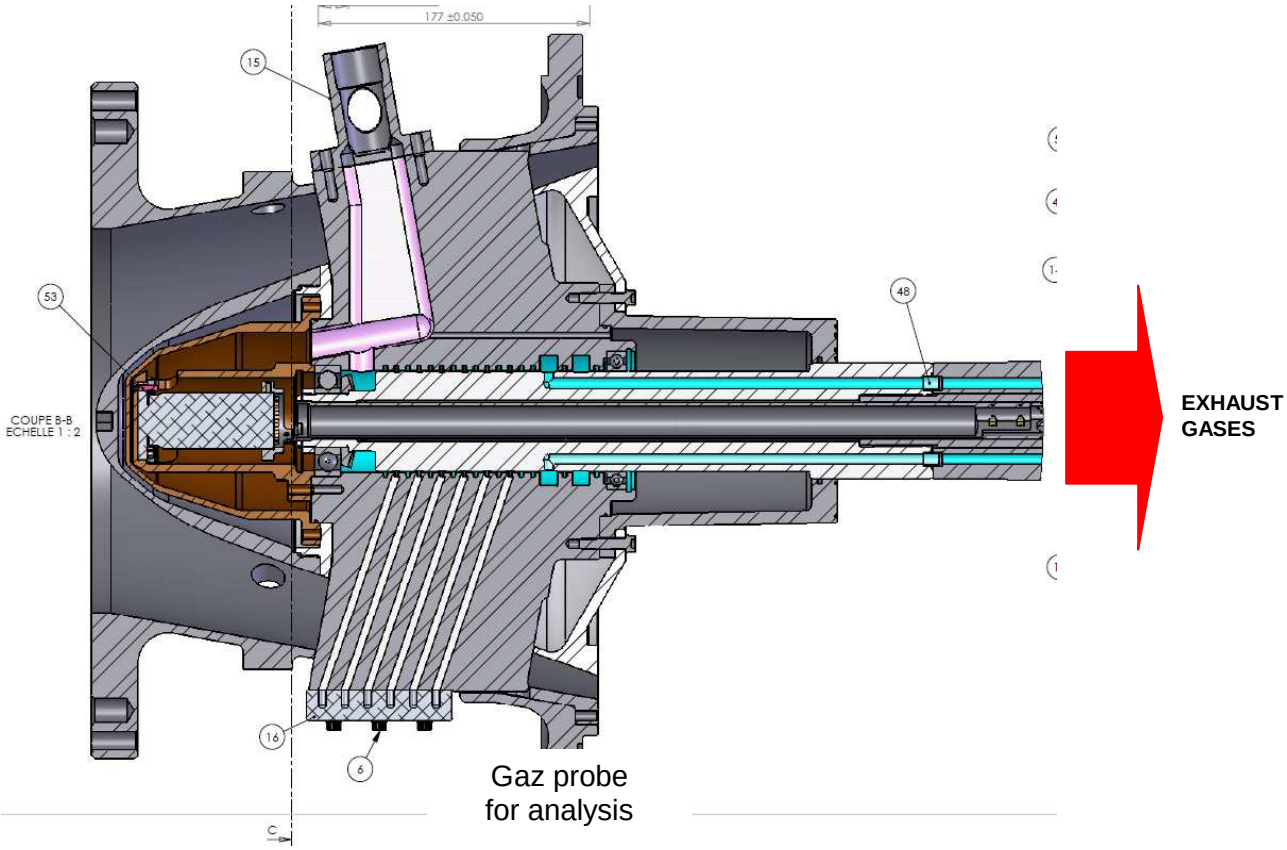


Figure 1: Drawing of the module with schematic view of the combustor (down)

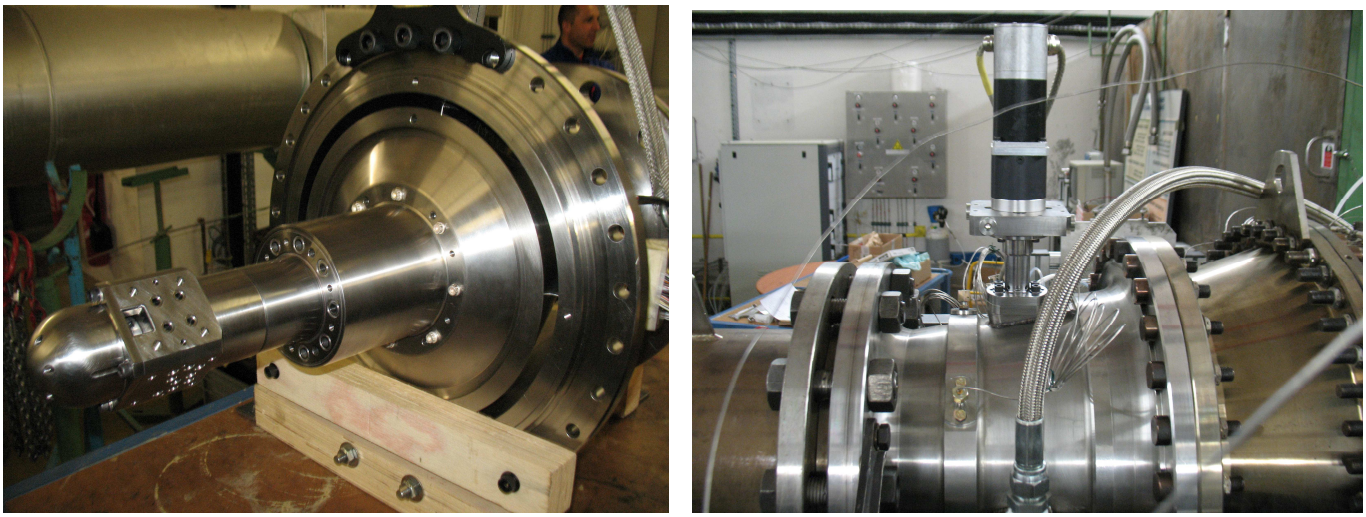


Figure 2: Photos of the module before the installation (left) and installed (right).

5.2 ACQUISITION RACK

Figure 3 gives a photo of the acquisition rack developed by AKIRA in the framework of NUMRSys. It includes:

- a PXI chassis with National Instrument boards devoted to the acquisition :
  - low and high rates for temperature (B and K type thermocouples)
  - complementary high frequency inputs,
  - exhaust gas concentrations delivered by the ‘’ANAGAZ’’ rack,
- DC voltage generator,
- power supply and the control unit of the stepper motor.

5.3 SOFTWARE

Akira developed a Labview software to perform both acquisition and automatic rakes displacement. It collects data from the test rig control unit (TURBOCAT) via FTP and gathers them to instantaneous data measured on the module trough the NATIA's rack via an optical fibre. It also performs data post processing: statistical and frequency analysis as well as temperature calculation based on exhaust gas analysis.

5.4 GENERAL ARRANGEMENT AND INTERFACES

Figure 4 gives a sketch of the general arrangement indicating the interfaces with the gas analysis device (ANAGAZ) and the test rig control unit (TURBOCAT), as well as the different type of data acquired on the module trough NATIA's rack.

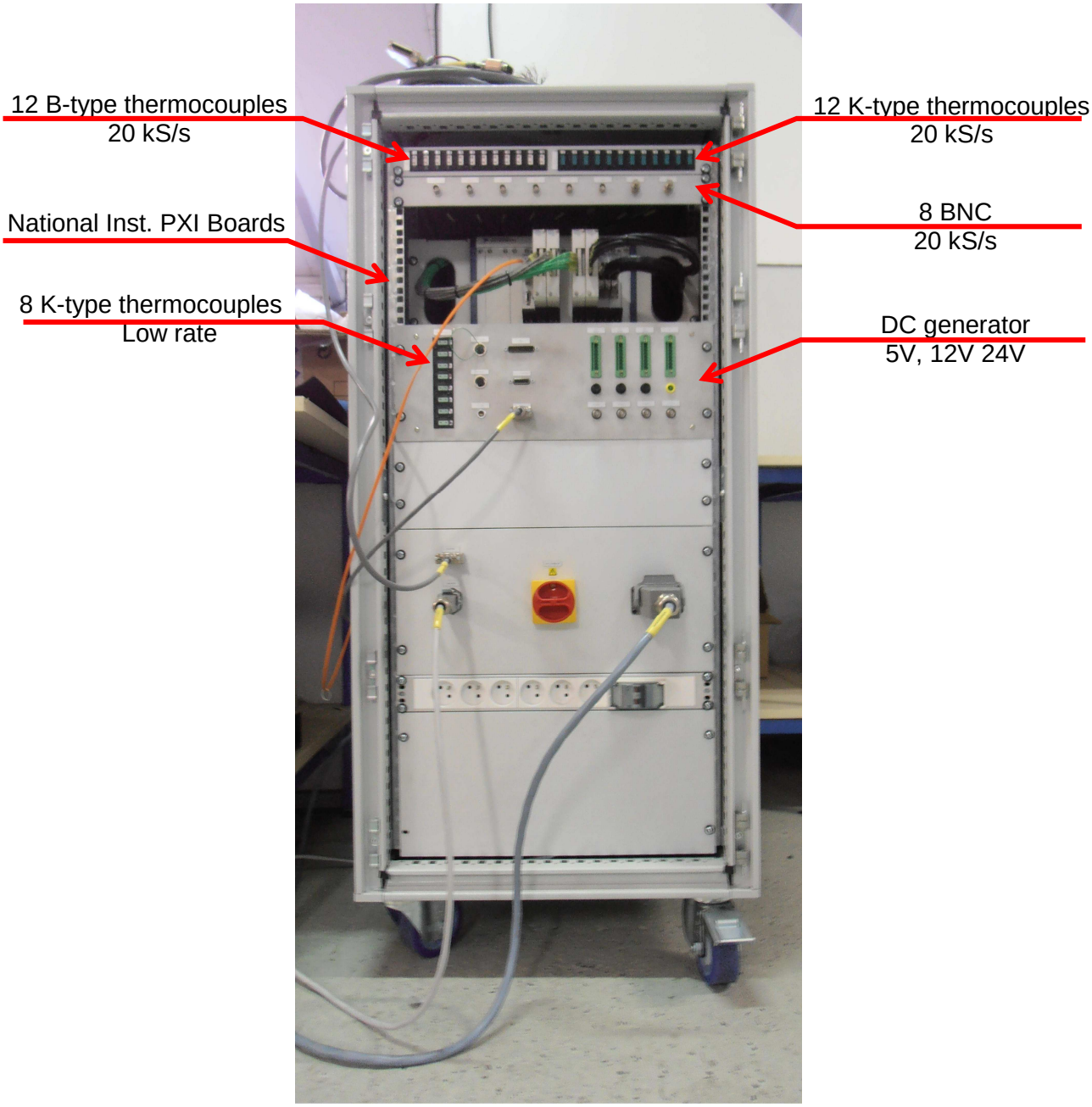
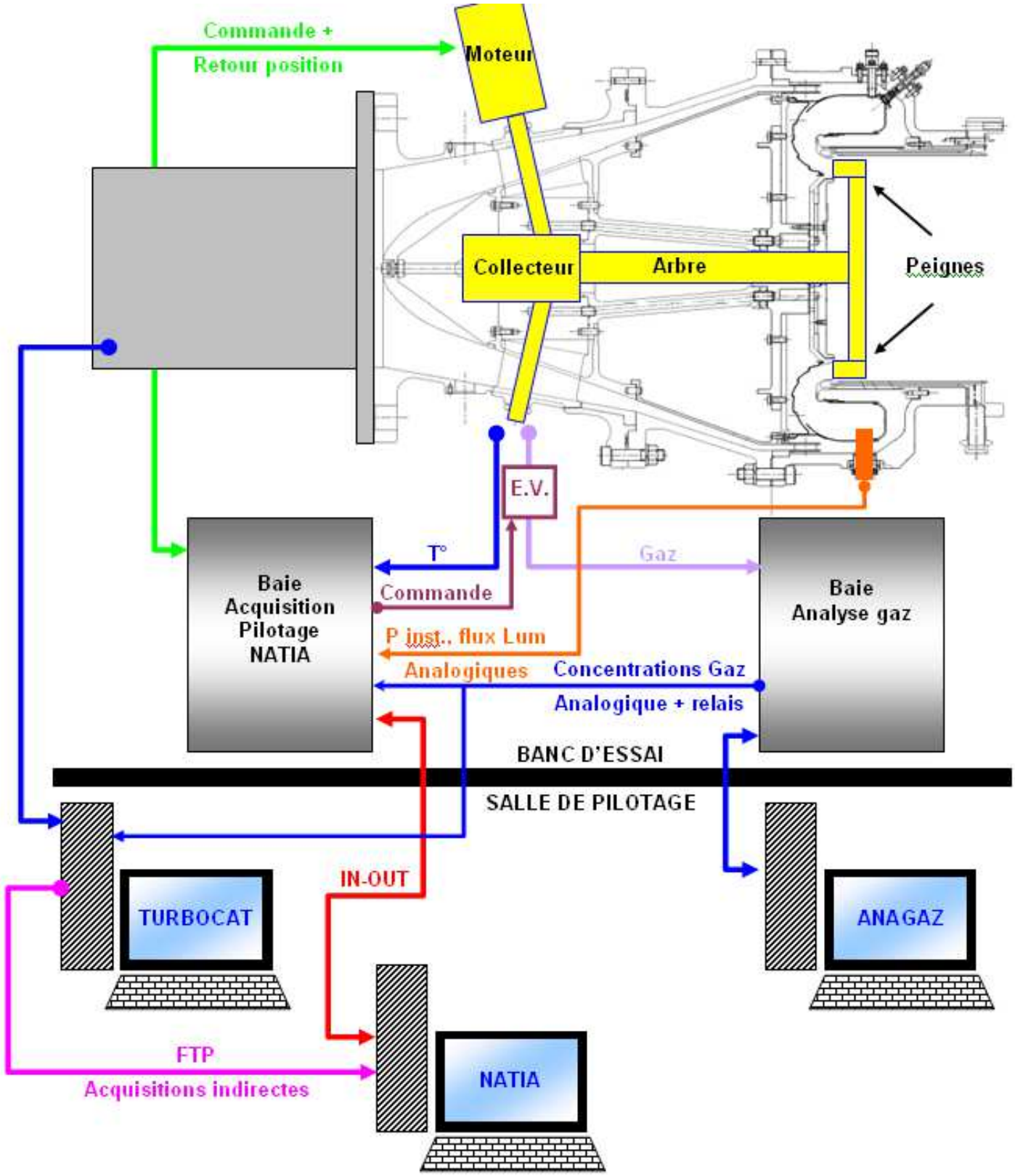


Figure 3: Acquisition rack



6 ASSESSMENT

Despite a delay of 15 months, the system developed with success by AKIRA corresponds to the need expressed by Turbomeca. Thanks to their competences, AKIRA performs a complex

work, including mechanical, electrical, electronic and software parts.